Interconnection Feasibility Study Report
Request # BHCT-G4

100 MW Generator at Airport Tap in Pueblo, Colorado

Black Hills Corporation
Transmission Planning

July 7, 2009

Executive Summary

Black Hills Corporation received an interconnection request (BHCT-G4) to interconnect a 100 MW gas turbine generator facility near Pueblo, Colorado. The proposed 100MW project consists of one (1) 100 MW GE LMS100 gas turbine with a primary Point of Interconnection (POI) at Airport Tap. An alternate POI was requested on the existing Airport Memorial-DOT Tap 115 kV line to a new substation tentatively named Nyberg. The proposed interconnect in-service date is October 1, 2011.

The request was studied as a Network Resource interconnected at both POIs with the full 100 MW rated output with heavy summer loads for the year 2012. Steady-state analysis was performed to evaluate the potential impact of the proposed interconnection on the Black Hills Energy transmission system and identify upgrades required to mitigate any performance criteria violations.

Interconnection Requirements

Based on the results of this study, the proposed 100 MW facility can be interconnected to the 115kV transmission system at the Airport Tap POI with the following system additions and upgrades:

- Rebuild 2.5 miles of 115kV line from Airport Tap to Airport Industrial Park.
- Rebuild 2.5 miles of 115kV line from Airport Industrial Park to Airport Memorial.
- Expand the Airport Tap 115kV substation by one (1) position.

These facilities are considered Network Upgrades with an estimated cost of **$3,750,000** and an expected in-service date of eighteen (18) months from the date of a signed interconnection agreement.

Interconnection Requirements – Alternate Location

The proposed 100 MW facility can be interconnected to the 115kV transmission at the alternate Nyberg POI with the following system additions and upgrades:

- Build a new three (3) position 115kV substation at Airport Tap.
- Recondition 5.2 miles of 115kV line from Airport Tap to Airport Tap 2.
- Build 4 miles of 115kV line from Airport Tap 2 to Nyberg.
- Expand the Nyberg 115kV substation by two (2) positions.

These facilities are considered Network Upgrades with an estimated cost of **$8,500,000** and an expected in-service date of eighteen (18) months from the date of a signed interconnection agreement.

Introduction

Black Hills Corporation received a Large Generator Interconnection request (BHCT-G4) to interconnect a 100 MW gas turbine generator facility near Pueblo, Colorado. The purpose of this Feasibility Study is to evaluate the potential impact on the Black Hills Energy transmission system and identify upgrades required to mitigate any performance criteria violations.

The proposed project consists of one (1) 100 MW GE LMS100 gas turbine with a primary Point of Interconnection (POI) at Airport Tap. An alternate POI, tentatively named Nyberg, was requested on the existing Airport Memorial – DOT Tap 115 kV line approximately 6.5 miles west of DOT Tap.

Power Flow Study Models

Power flow studies for the proposed interconnection were performed using PSS/E simulation software, version 30.3.3. The base case originated from the WECC approved 13HS1AP base case. This case was updated to include 2012 heavy summer loading and projects with in-service dates prior to the facility in-service date. The included projects, which were determined to have an impact on system performance, included:

- 200 MW Interconnection Request BHCT-G3 at Airport Tap 115kV *
- Airport Tap to West Station double circuit 115kV line **
- Second Boone 230/115 kV transformer
- Comanche 230/115 kV transformer updates
- LaJunta Tie Project

* When studying the alternate location of Nyberg, the 200 MW Interconnection Request BHCT-G3 was assumed to be located at Nyberg 115kV.

** When studying the alternate location of Nyberg, the Airport Tap – West Station double circuit 115kV line was replaced by a double circuit 115kV line from West Station to Nyberg.

The 100 MW of generation was dispatched by lowering the generation at Pawnee. The 100 MW facility was modeled as one (1) 100 MW generator. This machine modeled with its own 13.8 kV generator terminal bus and a 13.8/115 kV step-up transformer with maximum nameplate capacity of 125 MVA connected to the Airport Tap 115 kV bus. The estimated machine reactive capability curves provided with the application were used to set the reactive capability of the generator. When studying the alternate location, the 13.8/115 kV step-up transformer connected the generator terminal bus to the Nyberg POI 115 kV substation bus.

Power Flow Analysis

Power flow analysis was used to determine the impacts, if any, of the proposed 100MW of generation on the Black Hills Energy transmission system. The voltage and thermal performance of the system was evaluated with and without the proposed project in-service. Table 1 displays the voltage criteria used in this power flow analysis. Thermal loading on all transmission lines were not allowed to exceed 100% of their normal rating, while thermal loading on transformers were allowed to overload up to 120% as shown in Table 2.

Table 1 Steady-State Voltage Criteria

BHCT-G4 Feasibility Study		
Steady-State Voltage Criteria		
	Acceptable Voltage Range	
Voltage Class	**Pre-Contingency**	**Post-Contingency**
69kV and Above	0.95 to 1.05 p.u.	0.90 to 1.10 p.u

Table 2 Maximum Transformer Overloads

BHCT-G4 Feasibility Study	
Maximum Transformer Overloads	
Maximum Hours at Overload	**Allowable Transformer Overload**
1/2 Hour	153%
1 Hour	135%
2 Hours	120%

The steady state analysis was performed with pre-contingency solution parameters that allowed adjustment of load tap-changing transformers, static VAR devices including switched shunt capacitors and reactors, and DC taps.

Post-contingency solution parameters allowed for adjustment of DC taps only. Area interchange control was disabled and generator VAR limits were applied immediately for all solutions. A fixed-slope decoupled Newton solution method was implemented for all cases. Tables 3 and 4 list all of the prior outages and contingencies, respectively.

Table 3 Prior Outages Studied

BHCT-G4 Feasibility Study					
Prior Outages Studied					
PO#	**Prior Outage**	**PO#**	**Prior Outage**	**PO#**	**Prior Outage**
1	Burnt Mill - Freemary 115	16	W. Canon - Ponchbar 230	33	Comanche - Reader 115 #1
2	Burnt Mill - W. Station 115	17	Comanche - MidwayPS #1	34	MidwayPS - Northridge 115
3	Freemary - Reader 115	18	Comanche - Walsenburg 230	35	Boone 230/115 #T1
4	Overton - Apt Tap 115	19	Ftn Valley - Desert Cove 115	36	Comanche 230/115 #T1
5	Overton - Northridge 115	20	Ftn Valley - Midway BR 115	37	Comanche 345/230 #T3
6*	Apt Mem - DOT Tap 115	21	Hyde Park - Pueblo Plant 115	38	MidwayPS 230/115 #T1
6A*	Apt Mem - Nyberg 115	22	Hyde Park - W. Station 115	39	MidwayPS 345/230 #T2
6B*	Nyberg - DOT Tap 115	23	MidwayPS - W. Station 115 #1	40	W.Canon 230/115 #T1
7	Apt Park - Apt Tap 115	24	MidwayPS - MidwayBR 230	41	MidwayBR 230/115 #1
8	Apt Park - Apt Mem 115	25	Portland - Skala 115	42	Apt Gen 100MW #1
9	Boone - DOT Tap 115	26	Portland - W. Station 115	43	Comanche Gen #1
10	Boone - LaJunta W 115	27	Pueblo Plant - Reader 115	44	Comanche Gen #3
11	Boone - Comanche 230	28	Reader - Apt Mem 115	45	Lamar DC
12	Boone - Lamar CO 230 #1	29	Smelter - W. Canon 115	46**	W. Station - Apt Tap 115 #1
13	Boone - MidwayPS 230	30	Desert Cove - W. Station 115	46A**	W. Station - Nyberg 115 #1
14	Canon City - Skala 115	31	DanielPK - Comanche 345 #1	47***	Nyberg – Apt Tap 115kV
15	Canon City - W. Canon 115	32	MidwayBR - W. Canon 230		

* PO# 6 was used for studying the system intact case and 100 MW interconnection at Airport Tap. 6A and 6B were used for studying the 100 MW interconnection at Nyberg.

** PO# 46 was used for studying the 100 MW interconnection at Airport Tap and 46A was used for studying the 100 MW interconnection at Nyberg.

***PO #47 was only used for studying the 100 MW interconnection at Nyberg.

Table 4 Contingencies Studied

BHCT-G4 Feasibility Study Contingencies Studied					
#	Contingency	#	Contingency	#	Contingency
1	DANIELPK 345.00-COMANCHE 345.00 #1	32	APT_PARK 115.00-APT_MEM 115.00 #1	63	MIDWAYPS 230.00-MIDWAYPS 345.00 #T2
2	DANIELPK 345.00-COMANCHE 345.00 #2	33	W STATION 115.00-APT TAP 115.00 #1	64	COMANCHE 115.00-COMANCHE 230.00 #T1
3	WALSENBG 230.00-STMBEACH 230.00 #1	34	W STATION 115.00-APT TAP 115.00 #2	65	COMANCHE 115.00-COMANCHE 230.00 #T2
4	BOONE 230.00-COMANCHE 230.00 #1	35	CANONCTY 115.00-SKALA 115.00 #1	66	MIDWAYPS 115.00-MIDWAYPS 230.00 #T1
5	BOONE 230.00-LAMAR_CO 230.00 #1	36	CANONCTY 115.00-W.CANON 115.00 #1	67	W.CANON 115.00-W CANON 230.00 #T1
6	BOONE 230.00-LAMAR_CO 230.00 #2	37	COMANCHE 115.00-READER 115.00 #1	68	BOONE 115.00-BOONE 230.00 #T1
7	BOONE 230.00-MIDWAYPS 230.00 #1	38	COMANCHE 115.00-READER 115.00 #2	69	BOONE 230.00-BOONE 115.00 #T2
8	BOONE 230.00-STMBEACH 230.00 #1	39	BOONE 115.00-LAJUNTAT 115.00 #1	70	WALSENBG 115.00-WALSENBG 230.00 #T2
9	COMANCHE 230.00-MIDWAYPS 230.00 #1	40	BOONE 115.00-LAJUNTAW 115.00 #1	71	WALSENBG 115.00-WALSENBG 230.00 #T3
10	COMANCHE 230.00-MIDWAYPS 230.00 #2	41	HYDEPARK 115.00-PUEBPLNT 115.00 #1	72	STMBEACH 115.00-STMBEACH 230.00 #T1
11	COMANCHE 230.00-WALSENBG 230.00 #1	42	HYDEPARK 115.00-W.STATON 115.00 #1	73	MIDWAYBR 115.00-MIDWAYBR 230.00 #1
12	VILAS 230.00-LAMAR_CO 230.00 #1	43	LAJUNTAT 115.00-LAJUNTAW 115.00 #1	74	RD_NIXON 115.00-RD_NIXON 230.00 #1
13	LAMAR_CO 230.00-LAMAR_DC 230.00 #1	44	LAJUNTAT 115.00-WILOW_CK 115.00 #1	75	LAMAR_CO 115.00-LAMAR_CO 230.00 #T1
14	LAMAR_CO 230.00-CO_GRN 230.00 #1	45	MIDWAYPS 115.00-W.STATON 115.00 #1	76	DESERTCOV - FTN VAL - MIDWAYBR 115.00
15	MIDWAYPS 230.00-MIDWAYBR 230.00 #1	46	PONCHA 115.00-SMELTER 115.00 #1	77	MIDWAYPS - NORTHRIDGE - OVERTON 115.00
16	MIDWAYPS 230.00-FULLER 230.00 #1	47	PONCHA 115.00-N.GUNNSN 115.00 #1	78	BOONE - APT MEM 115.00
17	SANLSVLY 230.00-WALSENBG 230.00 #1	48	PORTLAND 115.00-SKALA 115.00 #1	79	BOONE - NYBERG 115.00
18	SANLSVLY 230.00-PONCHABR 230.00 #1	49	PORTLAND 115.00-W.STATON 115.00 #1	80	NYBERG - APT MEM 115.00 #1
19	MIDWAYBR 230.00-RD_NIXON 230.00 #1	50	PUEB_W 115.00-PUEB_TP 115.00 #1	81	APT TAP - W. STATION 115.00 DOUBLE CIRCUIT
20	MIDWAYBR 230.00-W CANON 230.00 #1	51	PUEB_TP 115.00-STMBEACH 115.00 #1	82	NYBERG - W. STATION 115.00 DOUBLE CIRCUIT
21	RD_NIXON 230.00-KELKER S 230.00 #1	52	PUEB_TP 115.00-W.STATON 115.00 #1	83	NYBERG - W. STATION 115.00 #1
22	RD_NIXON 230.00-FULLER 230.00 #1	53	PUEBPLNT 115.00-READER 115.00 #1	84	NYBERG - W. STATION 115.00 #2
23	RD_NIXON 230.00-FRTRANGE 230.00 #1	54	READER 115.00-APT_MEM 115.00 #1	85	MIDWAY - W.STATION AND MIDWAY NORTHRIDGE 115
24	W CANON 230.00-PONCHABR 230.00 #1	55	AREQUGCH 115.00-W.CANON 115.00 #1	86	AIRPORT GEN #1 - 100MW
25	PONCHABR 230.00-PARLIN 230.00 #1	56	SMELTER 115.00-W.CANON 115.00 #1	87	AIRPORT GEN #2 - 100MW
26	LAMAR_CO 115.00-WILOW_CK 115.00 #1	57	STMBEACH 115.00-WALSENBG 115.00 #1	88	COMANCHE GEN #1
27	BURNTMIL 115.00-FREEMARY 115.00 #1	58	DESRTCOV 115.00-W.STATON 115.00 #1	89	COMANCHE GEN #2
28	BURNTMIL 115.00-W.STATON 115.00 #1	59	W.STATON 115.00-MIDWAYBR 115.00 #1	90	COMANCHE GEN #3
29	FREEMARY 115.00-READER 115.00 #1	60	MIDWAYBR 115.00-RD_NIXON 115.00 #1	91	LAMAR DC
30	OVERTON 115.00-APT_TAP 115.00 #1	61	COMANCHE 230.00-COMANCHE 345.00 #T3	92	Nyberg – Apt Tap 115.00
31	APT_PARK 115.00-APT_TAP 115.00 #1	62	COMANCHE 230.00-COMANCHE 345.00 #T4		

Power Flow Results

Category B and C outages were studied using the methods described above. No relevant Category B or C violations existed for the system intact case. Table 5 shows the Category B and C violations for the 100 MW interconnection at Airport Tap, while Table 6 shows the 100 MW interconnection at Nyberg. Note that this table only shows thermal overloads as the simulations found no relevant voltage violations.

The power flow results showed that the limiting factors for the interconnection at Airport Tap were the Airport Tap – Airport Industrial Park and Airport Industrial Park – Airport Memorial 115kV lines. Based on these results, it was determined that the optimal solution for the 100 MW interconnection at Airport Tap would be to rebuild these two transmission lines. Figure 1 shows the network diagram with the Airport Tap interconnection and the required 115kV line rebuilds displayed in pink. With the addition of the 100 MW interconnection at Airport Tap and the two 115kV line rebuilds, there were no Category B or C violations.

The limiting factors for interconnecting at the alternate site of Nyberg were the Nyberg – Boone and Nyberg – Airport Memorial 115kV lines. The optimal solution for the 100 MW interconnection at Nyberg would be to recondition the existing out-of-service Airport Tap – Airport Tap 2 115kV line and connect this line to Nyberg by building an additional 4 miles of 115kV line from Nyberg to Airport Tap 2. Figure 2 shows the network diagram with the Nyberg interconnection and the required Airport Tap – Airport Tap 2 – Nyberg 115kV line displayed in pink. With the addition of the 100 MW interconnection at Nyberg and the 115kV line, there were no Category B or C violations.

Table 5 Category B and C Violations for the 100MW Interconnection at Airport Tap

Category B and C Violations							
		Prior Outage	No Prior Outage	Overton - Apt Tap 115	Overton - Northridge 115	Comanche Gen #3	Apt Tap - W. Station 115 #1
Overloaded Element	Rated MVA	Outage Description	%Ratings	%Ratings	%Ratings	%Ratings	%Ratings
Apt Park - Apt Tap 115	117	Apt Tap - W. Station 115 Double Circuit	162.1	-	-	-	-
Apt Park - Apt Tap 115	117	Apt Tap - W. Station 115 #1	-	118.8	114.4	100.1	-
Apt Park - Apt Tap 115	117	Apt Tap - W. Station 115 #2	-	118.8	114.4	114.4	162.1
Apt Park - Apt Tap 115	117	Overton - Apt Tap 115	-	-	-	-	118.8
Apt Park - Apt Tap 115	117	Overton - MidwayPS 115	-	-	-	-	115.7
Apt Park - Apt Tap 115	117	Comanche Gen #3	-	-	-	-	100.3
Apt Park - Apt Mem 115	122	Apt Tap - W. Station 115 Double Circuit	135.8	-	-	-	-
Apt Park - Apt Mem 115	122	Apt Tap - W. Station 115 #2	-	-	-	-	135.8

Table 6 Category B and C Violations for the 100MW Interconnection at Nyberg

Category B and C Violations									
		Prior Outage	No Prior Outages	Apt Mem - Nyberg 115	Nyberg - DOT Tap 115	Boone - DOT Tap 115	Comanche - Reader 115 #1	Comanche 230/115 #T1	Nyberg - W. Station 115 #1
Overloaded Element	Rated MVA	Outage Description	%Ratings	%Ratings	%Ratings	%Ratings	%Ratings	%Ratings	%Ratings
Nyberg - Apt Mem 115	122	Nyberg - W. Station 115 Dbl Ckt	132.7	-	-	-	-	-	-
Nyberg - Apt Mem 115	122	Nyberg - W. Station 115 #1	-	-	123.8	114.1	-	-	-
Nyberg - Apt Mem 115	122	Nyberg - W. Station 115 #2	-	-	123.8	114.1	-	-	132.7
Nyberg - Apt Mem 115	122	Reader - Comanche 115 #2	-	-	-	-	103.6	-	-
Nyberg - Apt Mem 115	122	Comanche 230/115 #T2	-	-	-	-	-	107.5	-
Nyberg - Apt Mem 115	122	Nyberg - Boone 115	-	-	-	-	-	-	123.8
Nyberg - DOT Tap	122	Nyberg - W. Station 115 Dbl Ckt	116.6	-	-	-	-	-	-
Nyberg - DOT Tap	122	Nyberg - W. Station 115 #1	-	117.8	-	-	-	-	-
Nyberg - DOT Tap	122	Nyberg - W. Station 115 #2	-	117.8	-	-	-	-	116.6
Nyberg - DOT Tap	122	Nyberg - Apt Mem 115	-	-	-	-	-	-	117.8
Boone - DOT Tap 115	122	Nyberg - W. Station 115 Dbl Ckt	102.8	-	-	-	-	-	-
Boone - DOT Tap 115	122	Nyberg - W. Station 115 #1	-	104.2	-	-	-	-	-
Boone - DOT Tap 115	122	Nyberg - W. Station 115 #2	-	104.2	-	-	-	-	102.8
Boone - DOT Tap 115	122	Nyberg - Apt Mem 115	-	104.2	-	-	-	-	104.2

Figure 1 Network Diagram for 100 MW Interconnection Upgrades at Airport Tap 115kV

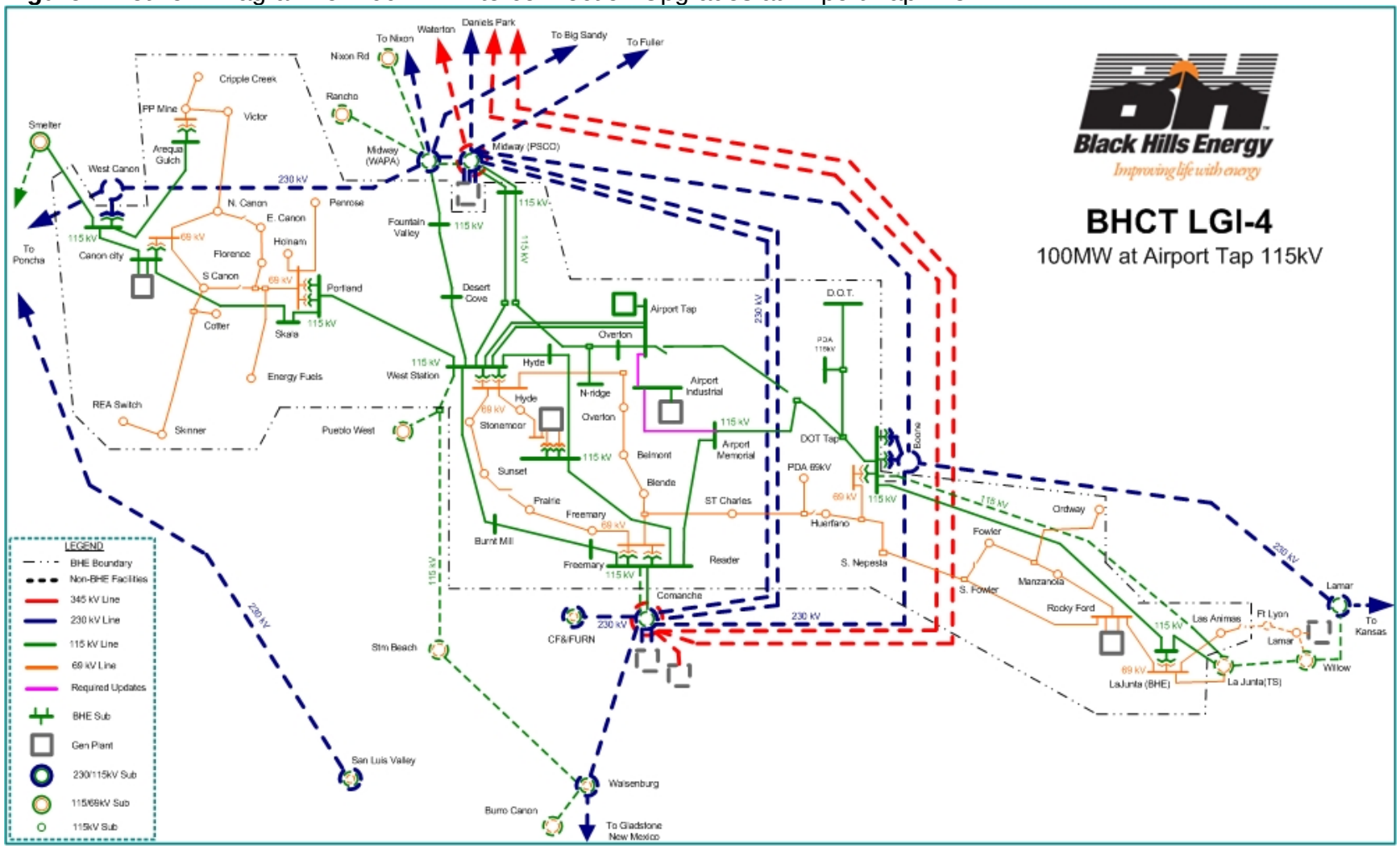
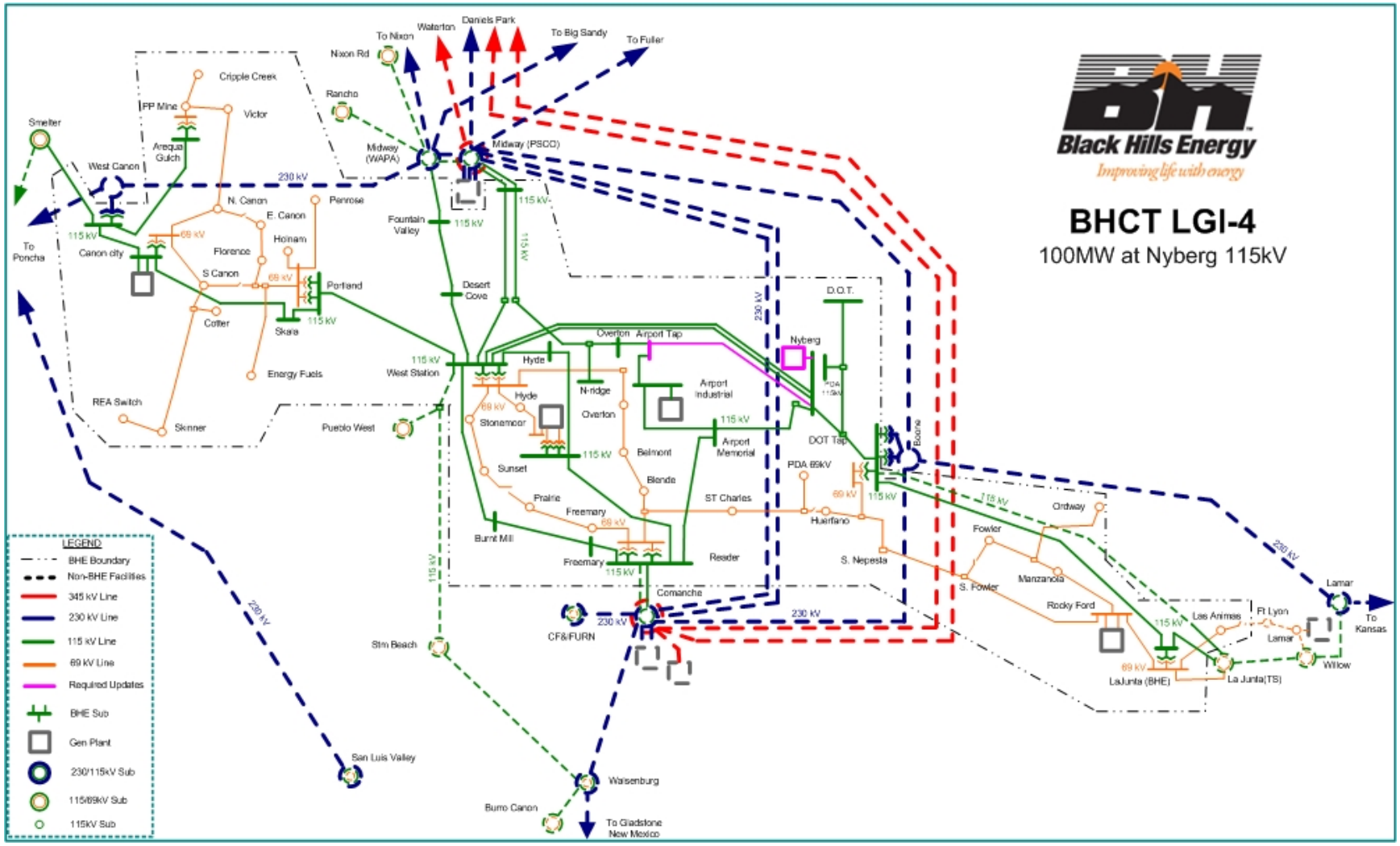


Figure 2 Network Diagram for 100 MW Interconnection Upgrades at Nyberg 115kV


Black Hills Energy
Improving life with energy
BHCT LGI-4
100MW at Nyberg 115kV
LEGEND
BHE Boundary
Non-BHE Facilities
345 kV Line
230 kV Line
115 kV Line
69 kV Line
Required Updates
BHE Sub
Gen Plant
230/115kV Sub
115/69kV Sub
115kV Sub
Smelter
West Canon
To Poncha
Canon city
Cripple Creek
PP Mine
Victor
Arequa Gulch
N. Canon
E. Canon
Penrose
Holnam
Florence
S Canon
Portland
Cotter
Skala
Energy Fuels
REA Switch
Skinner
Pueblo West
Nixon Rd
To Nixon
Waterton
Daniels Park
To Big Sandy
To Fuller
Rancho
Midway (WAPA)
Midway (PSCO)
Fountain Valley
Desert Cove
West Station
Hyde
Overton
Airport Tap
N-ridge
Stonemoor
Sunset
Prairie
Freemary
Burnt Mill
Belmont
Blende
Airport Industrial
Airport Memorial
ST Charles
Reader
Comanche
CF&/FURN
Stm Beach
San Luis Valley
Waisenburg
Burro Canon
To Gladstone New Mexico
Nyberg
D.O.T.
DOT Tap
PDA 69kV
Huerfano
S. Nepesta
Boone
Ordway
Fowler
S. Fowler
Manzanola
Rocky Ford
Las Animas
Ft Lyon
Lamar
Willow
LaJunta (BHE)
La Junta(TS)
To Kansas
230 kV
115 kV
69 kV

Conclusions

This report describes the power flow studies performed to determine the impacts of interconnecting an additional 100 MW to the proposed 200MW gas turbine generator facility near Pueblo, Colorado to the Black Hills Energy transmission system at Airport Tap 115kV, as well as the alternate location of Nyberg 115kV.

Based on the power flow simulations, the estimated total cost for the required interconnection at Airport Tap would be **$3,750,000.** These facilities are considered Network Upgrades with an expected in-service date of eighteen (18) months from the date of a signed interconnection agreement. Table 7 lists the required upgrades to accommodate the interconnection of 100MW at Airport Tap 115kV.

Table 7 Upgrade Costs for 100MW Interconnection at Airport Tap 115kV

BHCT-G4 Feasibility Study	
Upgrade Costs for additional 100MW at Airport Tap 115kV	
Cost in Millions	**Description**
$ 1.50	Rebuild 2.5 miles of 115kV line from Airport Tap to Airport Industrial Park
$ 1.50	Rebuild 2.5 miles of 115kV line from Airport Industrial Park to Airport Memorial.
$ 0.75	Expand Airport Tap 115kV substation (1 position)
$ 3.75	**Total Upgrade Costs**

Based on the power flow simulations, the estimated total cost for the required interconnection at Nyberg would be **$8,500,000.** These facilities are considered Network Upgrades with an expected in-service date of eighteen (18) months from the date of a signed interconnection agreement. Table 8 lists the required upgrades to accommodate the interconnection of 100MW at Nyberg 115kV.

Table 8 Upgrade Costs for 100MW Interconnection at Nyberg 115kV

BHCT-G4 Feasibility Study	
Upgrade Costs for additional 100MW at Nyberg 115kV	
Cost in Millions	**Description**
$ 5.25	Build new Airport Tap 115kV substation (3 positions)
$ 0.25	Recondition 5.2 miles of 115kV line from Airport Tap to Airport Tap 2.
$ 1.50	Build 4 miles of 115kV line from Airport Tap 2 to Nyberg.
$ 1.50	Expand Nyberg 115kV substation (2 positions)
$ 8.50	**Total Upgrade Costs**